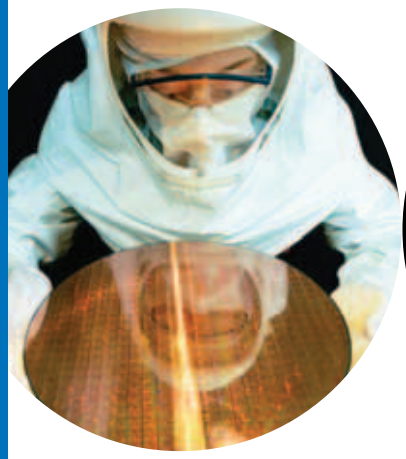
Technology and Research at Intel

Architectural Innovation for the Future



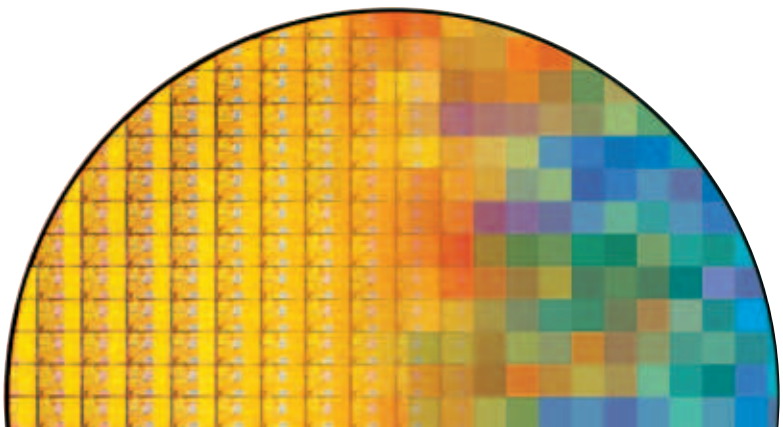
www.intel.com/technology

"Intel's primary technology and research goal is to enable everyone on the planet to be connected and computing. To date, products based on Intel® technologies have reached a billion users – which means we have five billion left to go. Our strategy is threefold: researching and developing the right technologies; enabling customers and partners to deliver the right end-user products; and collaborating with governments and standards bodies to define the right standards and policies. We envision a world where everyone is touched by our technologies, whether through traditional personal computing or consumer electronics, interactive or proactive devices."

Patrick P. Gelsinger
Senior Vice President
Chief Technology Officer
Intel Corporation

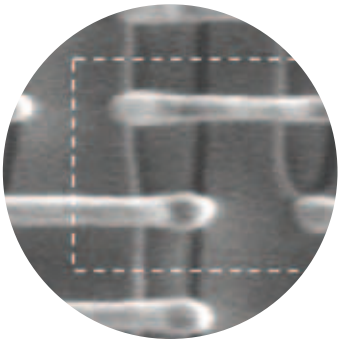
Innovating for the Digital World

Research and development at Intel is centered around convergence, the combination of computing platforms, communications, consumer electronics and newly created technologies that together drive new usage and business models, growth of the industry and growth in the number of users. The future of convergence depends not only on solid foundations in silicon and microarchitecture, but on a rich ecosystem of platform components and software, and on a business and regulatory infrastructure that allows technologies to interact smoothly and reliably. Our focus is to deliver platform value upon which customers may enhance operations and build new services. From silicon nanotechnology to globally deployed applications, the breadth and depth of our research and industry collaborations uniquely position Intel to accelerate the shift to a new world of services and information access virtually anywhere, any time and on any device.



Technology Focus Areas

Silicon Technology and Manufacturing



0.57 µm² SRAM cell on Intel 65 nm process.

Breakthroughs in silicon technology and manufacturing keep Intel in its leadership position and deliver competitive advantages to companies that base their products on Intel® architectures. Intel's leadership in silicon technology both extends Moore's Law, increasing performance while reducing manufacturing costs, and expands Moore's Law, bringing new capabilities into silicon and enabling new products optimized for a wider variety of applications.

Silicon Process Technology

Intel's **65 nanometer (nm) process technology**, on track for deployment in 2005, will extend our 15-year record of ramping production on a new process generation every two years. It will feature transistors measuring only 35 nm in gate length, which will be the smallest and highest performing CMOS transistors in high-volume production, and industry-leading second generation strained silicon. Strained silicon stretches or "strains" silicon atoms providing two benefits: first, it can increase transistor drive current which improves switching speed, resulting in faster chips; second, it can reduce transistor power, resulting in cooler chips. The second generation of Intel strained silicon will increase transistor performance by 10 to 15 percent without increasing leakage current.

By the end of the decade, Intel anticipates building chips with feature sizes as small as 15 nm using breakthrough **Extreme Ultraviolet** (EUV) **lithography**. EUV light has a wavelength of 13.4 nm, more than 10 times shorter than optical alternatives.

Materials Research

Intel researchers have developed record-setting, high-performance transistors using a new material, with a property called "high-k" for the gate dielectric and new metal materials for the transistor gate electrode. The combination of the **high-k gate dielectric** with the **metal gate electrode (High-K/Metal Gate)** enables a drastic reduction in leakage current while maintaining very high transistor performance. This is one of many advances that will make it possible to drive Moore's Law and technology innovation well into the next decade.

Silicon Photonics

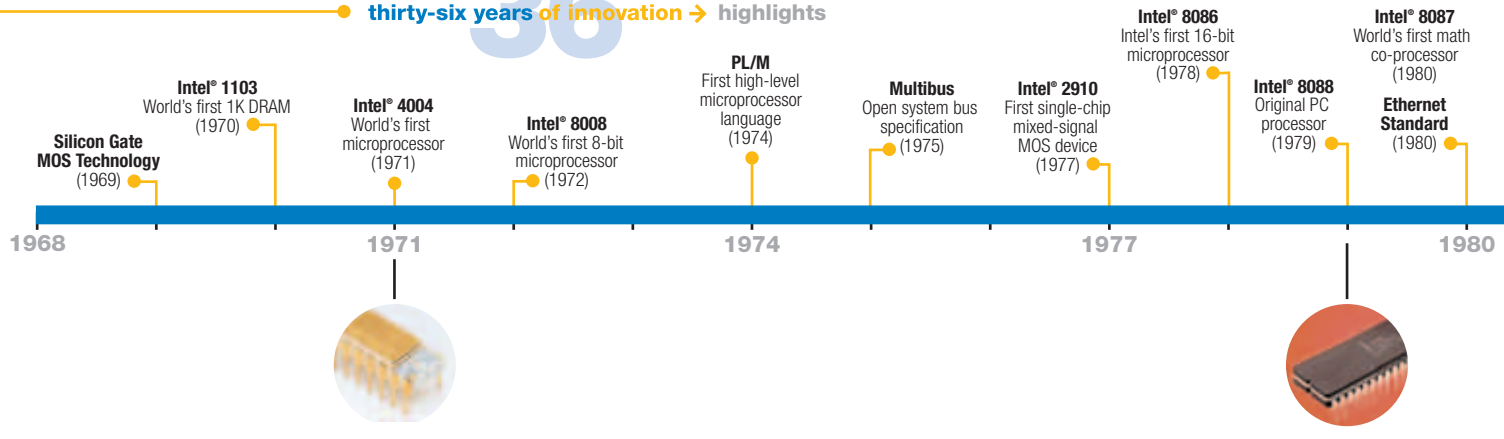
Silicon photonics brings optical networking technologies into silicon, extending the cost, size, and performance advantages of Moore's Law to a new and important arena. In addition to a breakthrough silicon-based optical modulator operating at 1 GHz modulation speed, Intel researchers are also addressing the challenges of optical packaging with passive alignment – the process of aligning two or more optical components without requiring active monitoring of the resulting output power.

Since packaging currently accounts for one-third the cost of optical modules, passive alignment will be essential to enabling high-volume silicon photonic technology and making optical networking practical and affordable.

"Intel's 65 nm process technology has industry-leading density, performance and power reduction features that will enable future chips with increased capabilities and performance."

Sunlin Chou
Senior Vice President and General Manager, Technology and Manufacturing Group, Intel Corporation

thirty-six years of innovation → highlights



Microarchitecture and Circuits

Raw processing performance is only one of several key vectors that will define future innovation in microarchitectures and circuit design. The next decade will see a number of architectural changes at both the micro and macro levels. These changes will drive and define architectural innovation, impacting the entire range of computing from the smallest sensor mote to the largest distributed computing cluster.

Circuit Design Techniques

As transistor count increases, Intel leads the industry in developing innovative circuit and microarchitectural structures to help meet power challenges. **Body biasing** allows controlling the body voltage of a transistor opportunistically, supporting higher speed when the circuit is functioning and lower leakage power when the circuit is not functioning. **Dynamic sleep transistor** is another innovative technique that adds a transistor in series with the power supply, which can be turned off when a block of logic circuitry is in idle mode, thus reducing current leakage. The body bias technique can be combined with a sleep transistor to provide even further leakage power savings.

Multi-core and multithreaded architectures will harness the growing number of transistors to handle compute intensive applications. These architectures will enable massive parallelism – the key to increasing performance within a given power envelope. Intel plans dual-core architectures for our server, workstation, desktop and mobile processors by 2006, and in the future, multi-core chips with four or more cores built onto a single piece of silicon. Multi-core technology will address future complex workload needs and enable capabilities like better user interfaces, data and content protection, and overall improved efficiency and performance.

Intel® Centrino™ Mobile Technology.

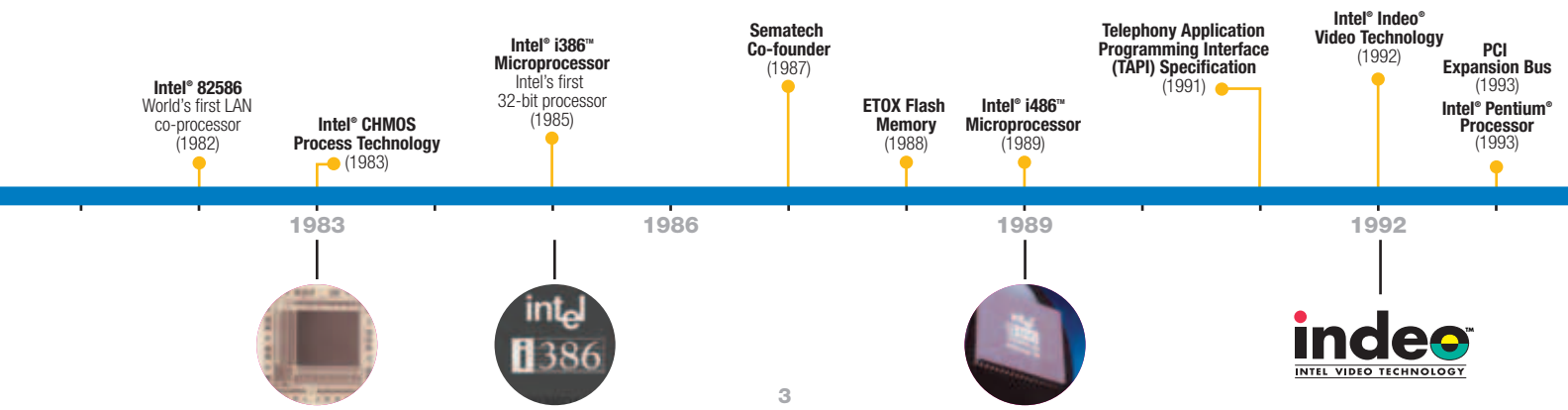
Researchers in Intel's Microprocessor Technology Lab.

Intel's next generation member of the **Intel® Itanium® processor family**, built on the 90 nm process, will feature dual cores, 1.72 billion transistors and Demand-Based Switching (DBS) with Intel Enhanced SpeedStep® Technology. DBS minimizes wasted energy by dynamically changing processor performance or power states via frequency and voltage scaling, based on utilization.

New Capabilities

Intel researchers have developed a set of technologies that represent an evolution in the way Intel®-based platforms are designed and used – the "*Ts" (for "T"echnologies). The *Ts provide significant user benefits over and above traditional frequency scaling. Current *Ts include:

Hyper-Threading Technology (HTT) from Intel, integrated into **Intel® Xeon™** processor family server products and **Intel® Pentium® 4** desktop products, enables two independent threads that allow one physical processor to appear and behave as two virtual processors to the operating system. HTT allows an increased number of applications to perform more seamlessly together, like simultaneous CD burning, video streaming



and virus scanning. Intel conceived the concept of hyper-threading as a seed vehicle in the Pentium 4 processor in 1999 to move our processors and supporting software into increasing degrees of parallelism.

Intel® Centrino™ Mobile Technology (CMT) represents Intel's most highly integrated technologies for mobile PCs. CMT consists of optimized components that are designed to deliver an outstanding mobile experience, featuring integrated wireless LAN capability, breakthrough mobile performance and extended battery life in a variety of mobile PC form factors. Intel Centrino Mobile Technology has been verified on tens of thousands of public Wi-Fi hotspot networks worldwide and supports leading security solutions like WEP and WPA2.

Future *Ts will include:

LaGrande Technology (LT) will provide a hardware-based security foundation that will help enable greater levels of protection for information stored, processed and exchanged on the PC.

Vanderpool Technology (VT) (client) and **Silvervale Technology** (ST) (server) provide hardware-based virtualization. Both are designed to enable multiple, independent software environments in a single platform providing improved system reliability, flexibility, responsiveness and quicker recovery from computer crashes.

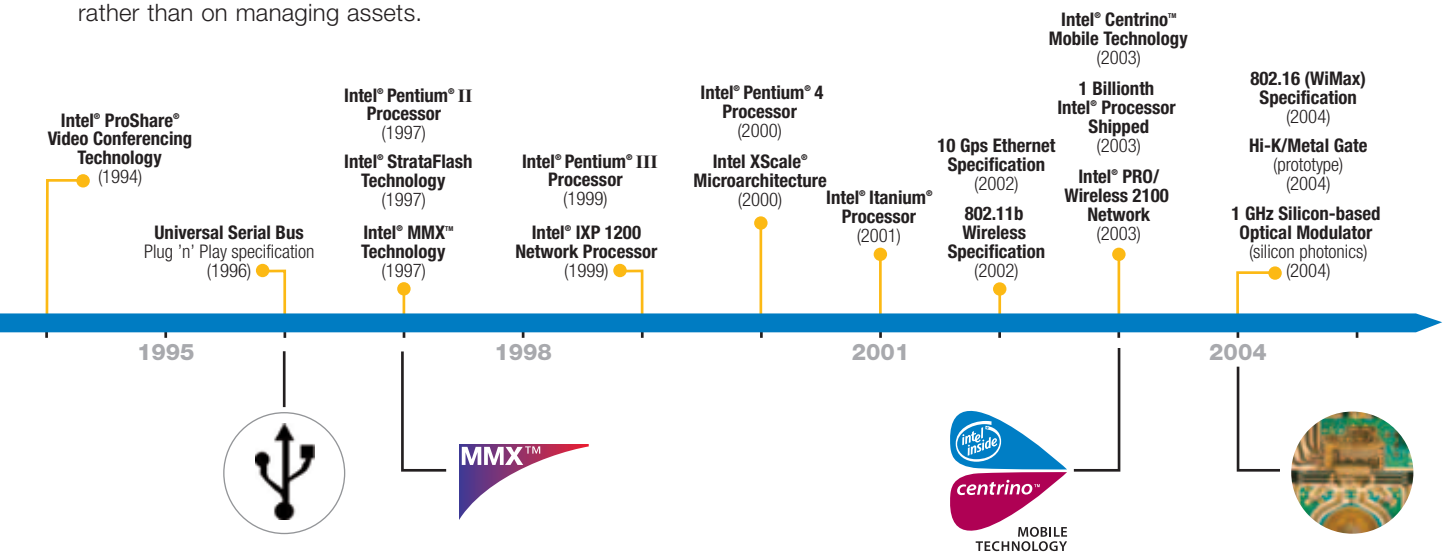
Intel® Active Management Technology (AMT) is designed to manage information across a variety of platforms, from handheld communications devices to servers. It will help IT managers concentrate resources and budgets on developing innovative solutions that help people work more efficiently, rather than on managing assets.

The Power Challenge

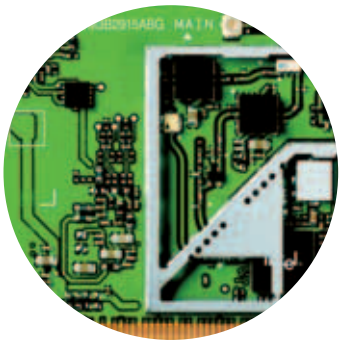
Power is a challenge to the entire semiconductor industry and nothing new to Intel. Smaller transistors consume less power, but as transistor density and speed rise, the overall chip consumes more power and generates more heat. In addition, power leakage, the continued flow of current even when the transistor is "off," becomes more problematic, wasting a higher portion of total device power. To meet this challenge, Intel is researching and developing a variety of novel power-saving techniques, including new transistor structures and materials, innovative approaches to circuit and microarchitecture design, advanced packaging materials, improvements to system components, and software optimization techniques.

For example, Intel's 65 nm process generation will combine several advanced power-saving technologies including new dielectric and interconnect materials, sleep transistors, and second-generation strained silicon to increase performance while reducing power consumption, heat and current leakage. New multi-core and multi-cluster microarchitectures will perform optimized load balancing through a combination of software and hardware mechanisms that dynamically examine the utilization, priority and thermal characteristics of a workload to match performance with power needs. Software developer tools such as the Intel® VTune™ performance analyzer conserve power by optimizing software code so that it takes less time to execute a given task.

The breadth and depth of Intel's R&D enables us to take a holistic approach to power challenges.



Communications and Networking



Intel® PRO/Wireless 2915 ABG Network Connection offers flexibility to connect to various Wi-Fi networks.

WiMAX base station delivering broadband wireless access to a metropolitan area.

"We believe that by adding computational capabilities, by embedding computation in the network at specific locations where it's needed, we can allow the Internet to evolve into something which is useful in interesting new ways."

Mic Bowman
Principal Investigator
PlanetLab Strategic Research Project, Intel Corporation

We live in an information society where emerging communications technologies will enable users to transcend the boundaries of time, place and distance. We are moving from standalone devices to device constellations that make communications and computing capabilities available to users anytime and anywhere. Intel is building on 30 years of computing and communications industry leadership to help bring this vision to life.

Pervasive Wireless Broadband

WiMAX, or 802.16, is a fast-emerging metropolitan area wireless broadband technology that shows great promise as the "last mile" solution for bringing high-speed Internet access into homes and businesses. The 802.16 standard will enable more hot spots and wider seamless roaming through the integration of WiMAX with Wi-Fi wireless LANs. Intel has taken a leadership position in the WiMAX Forum and is working with the industry to develop an end-to-end architecture for seamless and simple wireless connectivity. Intel will integrate WiMAX silicon into Intel Centrino mobile technology as an option in 2006.

Intel's Communications Technology Lab and Wireless Networking Group are working with the industry to promote adoption and deployment of standards-based protocols that will enable seamless roaming across multiple wireless and wired networks. The **International Roaming Access Protocol** (IRAP) framework for safe, simple, seamless connectivity will enable a better user experience at public Wireless LAN (WLAN) hotspots, and facilitate the implementation of one-bill roaming.

Intel® PRO/Wireless 2915 ABG Network Connection, Intel® PROSet/Wireless software v9.0 and Intel® PRO/Wireless 2200 bg Network Connection provide single-, dual-band and tri-mode wireless connectivity. The Intel PRO/Wireless 2915 Network Connection is the integrated WLAN solution for Intel Centrino mobile technology and is WPA2 certified.

Adaptive Radio

Wireless communication devices today come in many forms. Each device uses its own protocols and operates within a fixed segment of the frequency spectrum. Collectively, these devices create an inefficient scenario because they can neither communicate with each other nor provide backup to each other. Researchers at Intel have been working to develop the building blocks necessary for implementing an **adaptive radio** capable of enabling a single device to communicate across multiple frequency ranges and protocols.

The New Internet

Intel envisions a new Internet that benefits from convergence by adding a computationally intensive services overlay to the Internet's existing communications functionality. **PlanetLab**, a model for how this new Internet will emerge, demonstrates the workability and effectiveness of the services overlay by providing an open platform that allows researchers to create and deploy very large distributed applications that span a significant portion of the global Internet. Intel launched the PlanetLab project by contributing the first 100 nodes, the initial software implementation and awarding research grants to a number of universities. Intel is now a charter member of the PlanetLab Consortium, a collection of academic, industrial and government institutions cooperating to support and enhance the PlanetLab overlay network.

There are more than 440 PlanetLab nodes up and running at 190 sites in 22 countries around the globe.

Computing Platforms

The mission of platforms research at Intel is to deliver world-class systems technology and platform architectures for Intel's future silicon products. By collaborating with industry, universities and Intel business units, research in our Systems Technology Labs aims to combine Intel silicon components into powerful, cost-effective systems to support future computing applications.

Low Power on Intel® Architecture

The evolution of communications and computing technology offers the promise of a more productive, more entertaining and creative future with the help of a variety of embedded and handheld computing devices. The ability to achieve this vision depends on effective power management at the transistor, component and system level for these pocket-sized and smaller computer systems. Researchers at Intel are developing power management policies and metrics for future Intel-based platforms that address the critical issues of battery life, heat dissipation, and overall power management for future small form-factor, high-performance devices.

Focused on system software policy management, researchers on the **Low Power on IA** (LPIA) project are defining architecture "modes" (e.g., Personal Video Player) and power optimizations, researching system-level power states and aggressive power management policies, developing power metrics to calibrate power management in handheld devices, and focusing future efforts on close cooperation with OS vendors for implementation.

Intel researchers are achieving architectural innovations to realize the vision of pervasive technology that can improve every aspect of our lives.

Platform Manageability

Intel's **Handheld Manageability** research aims to enable consistent, standards-based pre-boot management and provisioning on all Intel-based handheld clients. The Handheld Manageability project is developing pre-boot, OS-independent manageability via **Extended Firmware Interface** (EFI) technology. EFI-based manageability helps make handheld devices into highly reliable and manageable platforms with low total cost of ownership.

The goal of Intel's **Service Oriented Enterprise** (SOE) initiative, a modular approach to better architect an enterprise environment, is to enhance IT responsiveness and management of diverse systems. SOE combines elements of mobility, grid computing and manageability into a framework to assist IT managers using all or some of these technologies to transform their businesses. It also provides a framework for enabling new capabilities and services such as RFID and Voice Over IP telephony.

High-Performance Computing

The **Intel Advanced Computing Center** (Intel ACC) is working to bring High-Performance Computing (HPC) capabilities to the mainstream. Research and development projects funded by Intel ACC include CPU architectures, platform architectures, system software, programming environments and application workloads.

Intel® 915G Express Chipset with Intel® Graphics Media Accelerator 900 improves the response time when running desktop applications concurrently.

Next-generation Itanium will support High-Performance Computing with dual-core architecture.

Catalyzing the Industry

Intel's ongoing commitment to developing and promoting standards includes contributions of advanced technology and expertise. To overcome technical and regulatory barriers, Intel actively works with universities, government agencies and influential industry groups including the European Telecommunications Standards Institute (ETSI), European Commission, Ministry of Information Industry (MII) in China, International Telecommunications Union (ITU), Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT) in Japan, and the Federal Communications Commission (FCC). For example, Intel works with worldwide regulatory bodies to advocate reforms in spectrum policy in order to enable the success of technologies such as Wi-Fi, WiMAX and Ultra-WideBand.

Intel has the vision of interoperable, networked devices in the home, and is a founding member of the **Digital Living Network Alliance**, whose goal is to deliver an interoperable framework of design guidelines based on industry standards and marketing support programs. Part of realizing the digital home vision is ensuring that there are solid **content management** technologies in place. Intel works with content providers, systems implementors, and government bodies in designing these technologies that balance consumer expectations with content holder rights. Some examples of these technologies include:

Content Scramble System (CSS) – protects video content distributed on DVD. This is the most widely used content protection technology for media.

Content Protection for Pre-Recorded Media (CPPM) – protects pre-recorded DVD audio content. Record labels encrypt content and license access keys to individual playback devices.

Digital Transmission Content Protection (DTCP) – provides protected transmission of audio/video content as it travels between digital devices over home networks.

High-Bandwidth Digital Content Protection (HDCP) – a specification developed by Intel to protect digital content across HDMI and DVI interfaces (connects devices to digital displays and contributes to safe, flexible use of digital content).

Security

Intel helped found the **Trusted Computing Group** (TCG) – an incorporated industry working group chartered with making computers more secure. Since its inception in 2003, the TCG has worked to standardize hardware and software interfaces that will allow interoperability across multiple platforms and provide better protection for online interaction.

Interoperability

The nonprofit **WiMAX Forum** was formed by Intel and other leading companies to promote and certify the compatibility and interoperability of wireless broadband equipment.

Connectivity

In 2003, Intel helped form the **MultiBand OFDM Alliance** (MBOA) with several key players in the consumer electronics, PC, semiconductor and digital imaging market segments. This organization's goal is to develop the best technical solution for the emerging **Ultra-WideBand** (IEEE 802.15.3a) PHY and MAC specification for a variety of applications. UWB is short-range radio technology that is designed to bring high-speed connectivity in devices throughout the digital home and office. It is designed to complement other longer range radio technologies such as Wi-Fi and WiMax.

Intel's leadership in developing industry standards and influencing technology policy worldwide strengthens our ability to address the broad range of technical challenges and industry opportunities that are a part of the converged future.

Taking holiday photos in the digital home.

"The PC and consumer electronics industries must work together to specify open standards for digital home products if we are to create a much larger playing field for both industries. We need to collaborate before we compete."

Louis Burns
Vice President & General Manager
Desktop Platforms Group, Intel Corporation

Intel® Technology Applied

The scope of Intel's research and development extends beyond technology itself to consider how technology broadly influences the world in which we live. Intel's aim is to create new technologies and new uses for technology that enhance daily life. Intel anthropologists, psychologists and ethnographers work with Intel computer scientists and product developers and with academic and industry researchers around the world to understand how people actually use technology in their daily lives and to design new technologies to meet real world needs.

Proactive Health

Today, over half the world has limited access to healthcare. In the future, technology may help improve people's health in even the most remote regions of the globe. Intel's **proactive health** research combines wireless technology, sensors that monitor patient health, and distributed database technologies to create systems that will help bring quality healthcare to patients all over the world.

Precision Biology

There is a tremendous convergence opportunity for biology, medicine and nano-scale silicon technology. The goal of Intel's Precision Biology research is to combine Intel's nanotechnologies with aspects of biology and medicine to make it possible to use microchips in fundamentally new ways. The team is conducting long-range research to create advances in sensor technology, and to work together with the medical community to make it possible to one day use chips to diagnose disease and improve people's health. To launch the effort, Intel is building an **Intel Raman Bioanalyzer System**™ at the Fred Hutchinson Cancer Research Center in Seattle. The instrument beams lasers onto tiny medical samples, such as blood serum, to create images that reveal the chemical structure of molecules. The goal is to determine if this technology, previously used to detect microscopic imperfections on silicon chips, can also detect subtle traces of disease.

"The challenge of delivering quality, affordable healthcare is enormous, and it's pretty clear that prevention and proactivity are key to cost savings. We want to make sure people are proactive about their own health."

Eric Dishman
Manager Proactive Health
Strategic Research Project
Intel Corporation

Investing in the Future

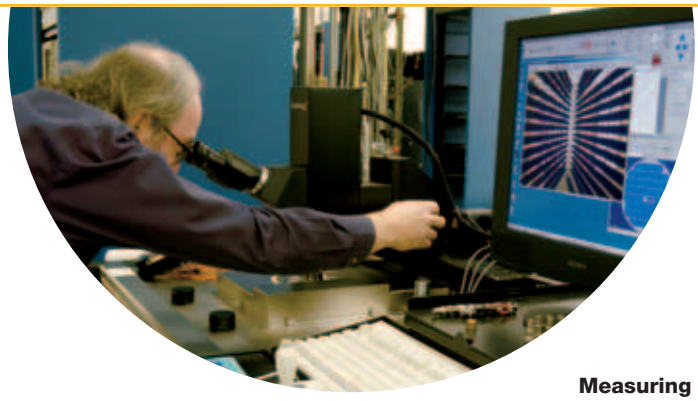
Intel is architecting the future of computing and communications by investing nearly $5 billion annually in research and development.

Intel's unique research and development model emphasizes a collaborative approach to technology identification and innovation, and standards development and regulatory policy to accelerate technology adoption and deployment.

Research and development at Intel features a decentralized worldwide network of researchers, scientists and engineers who are pioneering technology innovation in the computing and communications industry.

Intel Capital, Intel Corporation's strategic investment program, supports and fosters research through capital investments in promising technologies and through participation in a number of industry consortia. Since its inception in the early 1990s, Intel Capital has invested in more than 1,000 IT companies in more than 30 countries. In 2003, Intel Capital invested about US $700 million in 120 companies worldwide, of which 40 percent were based outside the U.S.

Through research and development, and strategic investments, Intel is developing and accelerating the technologies and products necessary to make anytime, anywhere, any device computing and communications a reality.



Measuring performance characteristics of devices on 300 mm wafer.

Working Together

Intel's success starts with development of outstanding building block technologies, but it ultimately depends on fostering a robust ecosystem of innovation and removing roadblocks to our customers' success. To help ensure that success, we're investing nearly $5 billion annually to keep our products and technologies on the leading edge and enable our customers to create solutions based on Intel products and technologies that delight consumers and deliver outstanding business value.

Take advantage of Intel's hard work. Learn more about Intel's technology and research activities. Understand how Intel's technology advances and industry enablement activities can create opportunities for your business. Maximize your success and accelerate your time to market by using Intel-based platforms and tools.

Together, we can build the future.

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